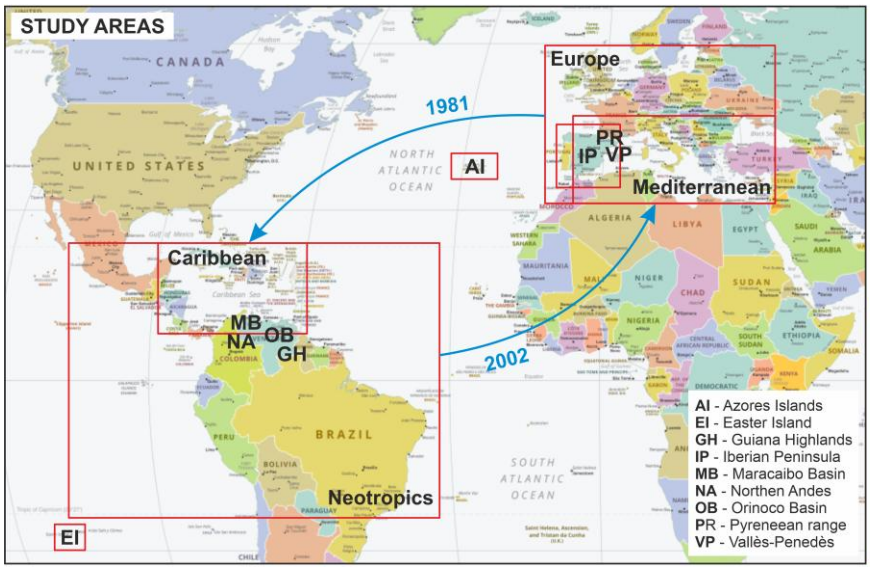
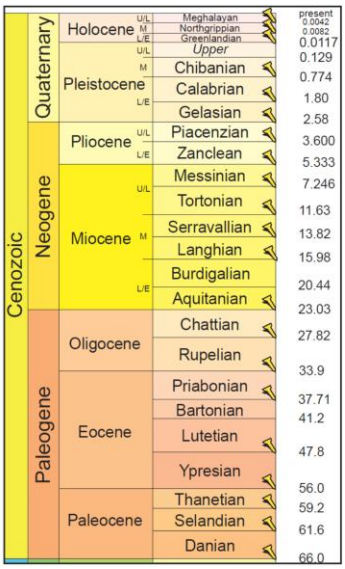
CAREER SUMMARY

BIOGRAPHY

- Valentí Rull del Castillo
- Born in Ribes de Freser, Catalonia, Spain (1956)
- Licenciate in Biological Sciences. University of Barcelona (UB), Spain (1981). Advisor: R. Margalef
- Moved to Venezuela (1981), at age 25 (see map)
- MS (1985) and PhD (1991) in Ecology, specialty in Paleoecology. Venezuelan Institute for Scientific Research (IVIC). Advisors: M.L. Salgado-Labouriau and C. Schubert
- Biostratigrapher (Palynologist). Petróleos de Venezuela (PDVSA) (1990-2002)
- Came back to Spain (2002), at age 46
- Ramón y Cajal Researcher (2003-2004) and Associate Professor (2004-2008). Autonomous University of Barcelona (UAB), Spain (2003-2004)
- Senior Researcher. Spanish National Research Council (CSIC) (2008-2026)
- Retirement in January 2026, at age 70





MAIN ACHIEVEMENTS

- Featured in the *Stanford ranking* of highly influential scientists, within the top 0.5% paleontologists and the top 10 palynologists
- Not interested in honors, awards or similar recognitions

MAIN APPOINTMENTS

- Director of the Botanical Institute of Barcelona (CSIC)
- Member of the Scientific Evaluation Committee of Marie Curie Actions and ERA-NET Biodiversa (EU FP7)
- Coordinator of *PAGES* (Past Global Changes) for Venezuela
- Editor-in-Chief of 2 (one as founding editor) and Associate Editor of 6 international journals

TEACHING

- Undergraduate courses: Botany (UAB)
- Postgraduate courses: Palynology (UAB, PDVSA), Paleoecology (CSIC, UAB, UB), Biostratigraphy (PDVSA)
- Students advised: 6 graduate, 11 MS, 6 PhD and 2 postdocs (UAB, UB, CSIC, PDVSA)

RESEARCH PROJECTS

- Participation in 40 national and international projects, 14 as principal investigator

RESEARCH INTERESTS

General

- Cenozoic plant ecology, evolution and biogeography

Specific topics

- Biotic responses to environmental change, from organisms to biomes
- Complex environmental-human-ecological dynamics
- Microrefugia and macrorefugia
- Holistic ecosystem recconstruction using plant and animal fossils
- Influence of Cenozoic climates and tectonics on present biodiversity and biogeograpy
- Origin of tropical biodiversity and the latitudinal biodiversity gradient
- Origin and evolution of tropical mangroves
- Historical biogeography of iconc plants: *Mauritia* and *Cannabis*
- Paleoecology of pristine tropical areas
- Plant extinction and biotic turnover across characteristic geological boundaries
- Biostratigraphy and ecostratigraphy applied to oil exploration
- Paleoecology, human settlement and anthropization of remote oceanic islands
- Mountain paleocology and anthropization trends and patterns
- Standard high-resolution Lateglacial and Holocene sedimentary sections
- Paleoecological potential of chrysophyte cysts

Methodological matters

- Palynological sampling and counting methods
- Modern analog studies applied to paleoecological interpretation
- High-impact ecostratigraphical methods in exploration biostratigraphy

Theoretical and conceptual issues

- The time-continuum approach
- Ecology, paleoecology and the missing link
- Disequilibrium ecological dynamics
- The evolutionary time arrow
- The Anthropocene
- Ecological hypothesis testing using paleoecology
- Paleoecology and biodiversity/ecosystem conservation
- Evolutionary laws and predictability
- Reductionism and biological uniqueness

Science and society

- The future of humankind
- Conservation and sustainable development
- Sixth extinction
- History of science
- Scientific research and its applications
- Free science and slow science

STUDY AREAS (see map)

Europe

- Pyrenees and pre-Pyrenees
- Vallès-Penedès basin

- The Iberian Peninsula as a whole (*Cannabis* meta-analyses)
- The Mediterranean-Paratethys region (Miocene mangroves)
- Europe as a whole (Cenozoic mangroves)

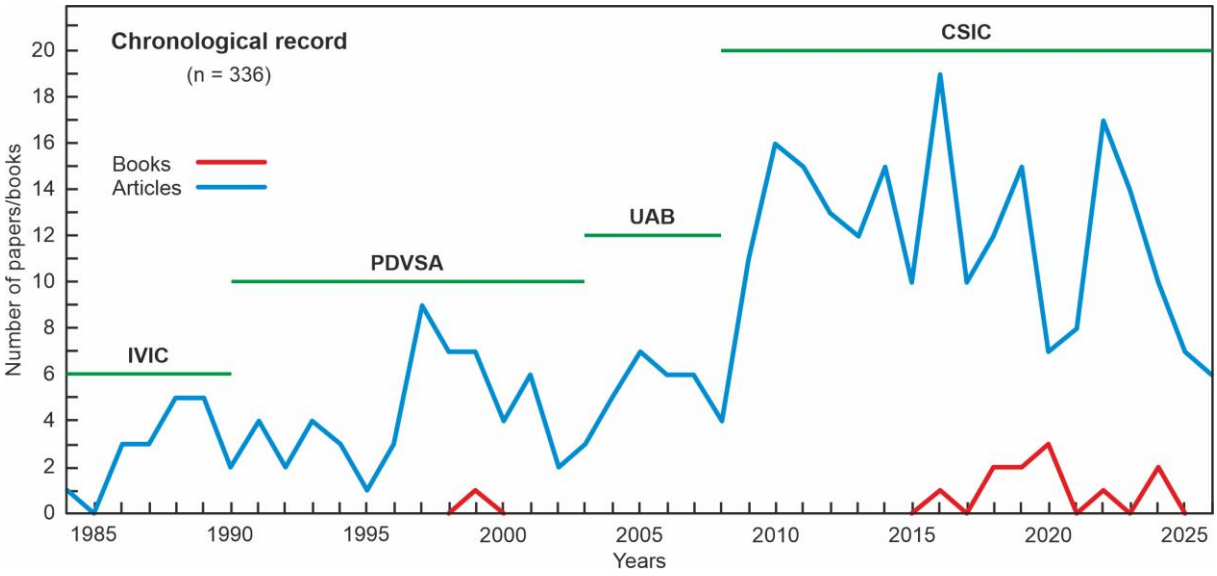
Neotropics (American tropics)

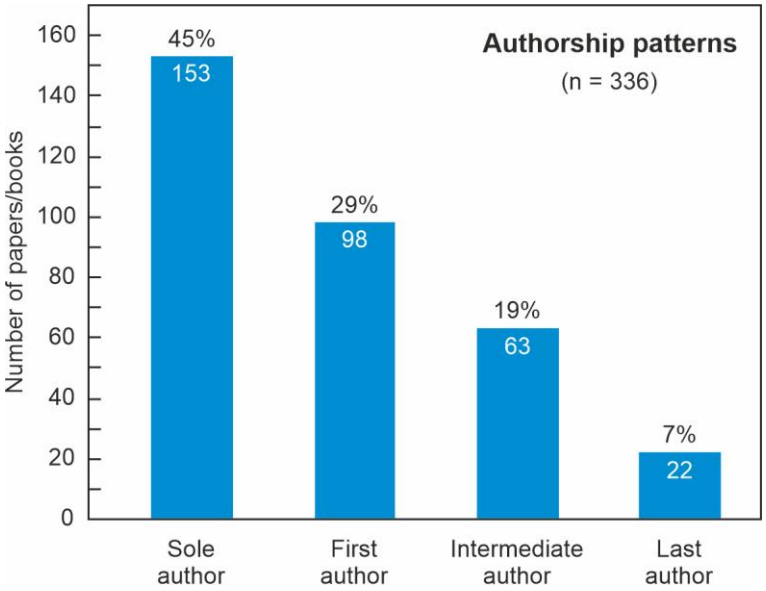
- Northern Andes
- Orinoco basin and delta
- Highlands (Pantepui) and midlands (Gran Sabana) of the Guiana region
- Maracaibo basin
- The Caribbean Sea as a whole (mangrove meta-analyses)
- The Neotropics as a whole (biodiversity meta-analyses)

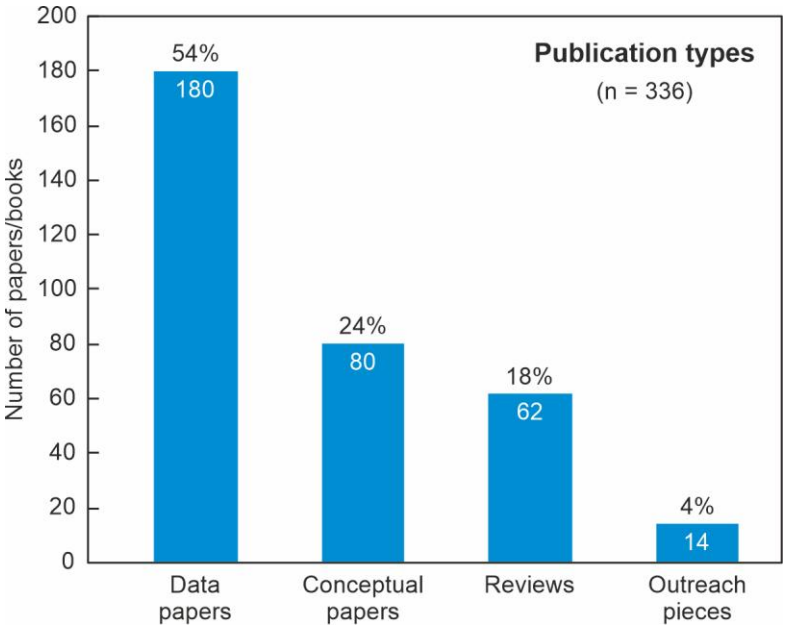
Oceanic islands

- Rapa Nui (Easter Island) (Pacific Ocean)
- Azores Islands (Atlantic Ocean)

PUBLICATIONS



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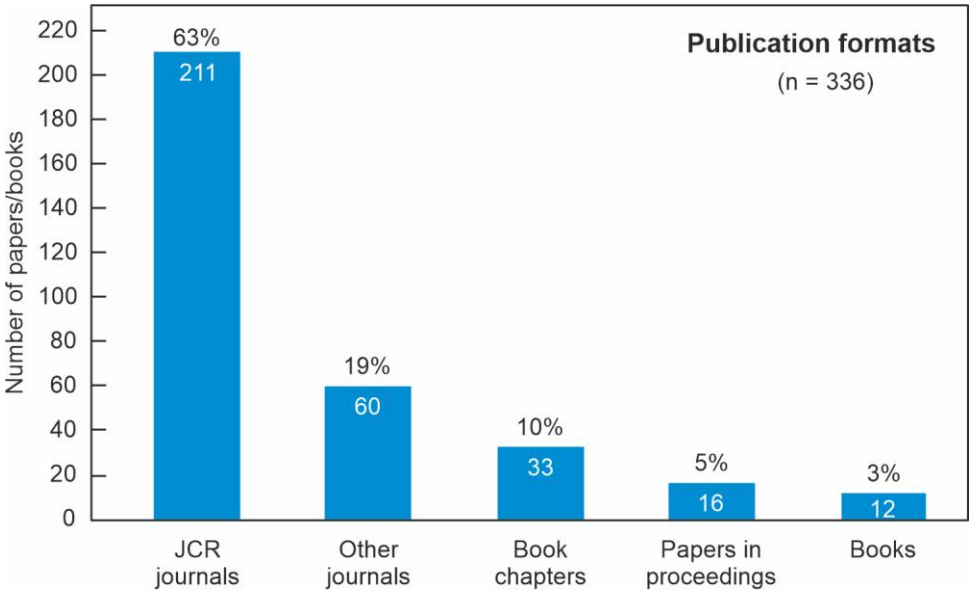
Conceptual papers
Reviews
Outreach pieces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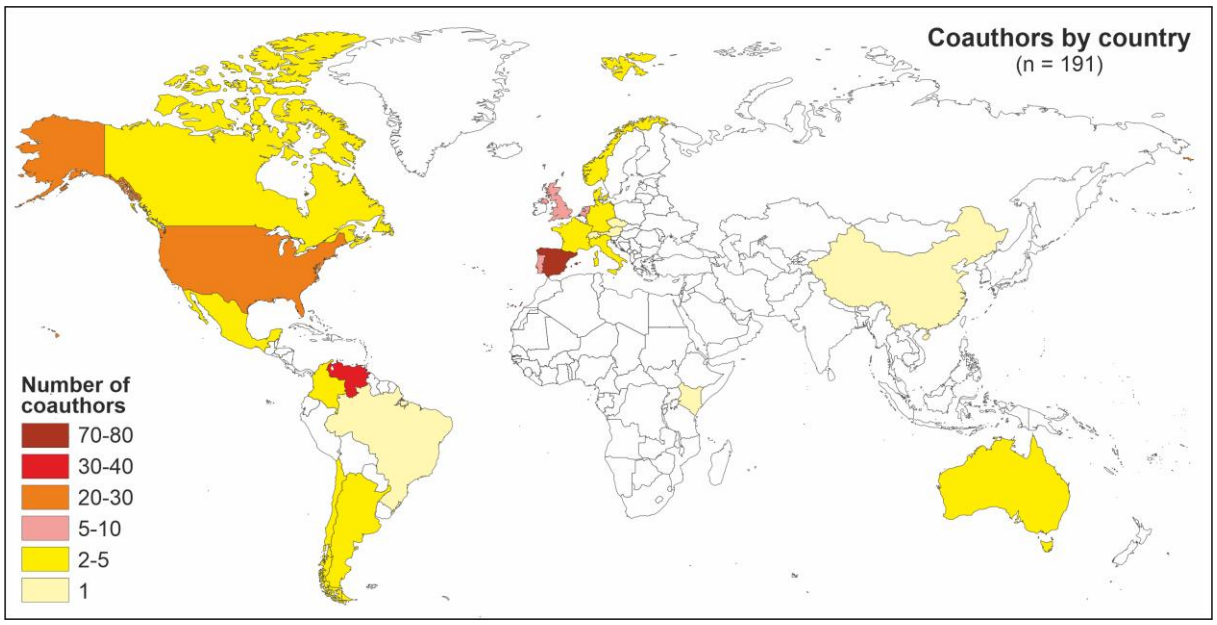
Books


Coauthors by country
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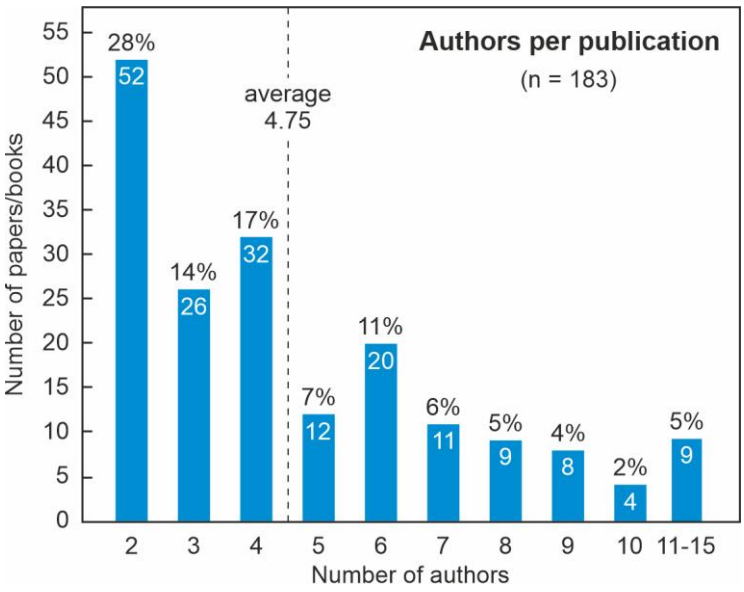
2-5
1



- No hyperauthored papers (>15 authors)
- No questionable or unethical authorship practices (guest, honorary, gift, ghost, reciprocal, etc.)

Major book publishers

- *Springer Nature*
- *Elsevier*
- *Academic Press*

Selected high-impact journals

- *Nature*
- *Science*
- *Proceedings of the National Academy of Sciences USA*
- *Trends in Ecology and Evolution*
- *Biological Reviews*
- *Earth-Science Reviews*
- *Communications Earth & Environment*
- *Global Change Biology*
- *Science of the Total Environment*
- *Global Ecology and Biogeography*
- *EMBO Reports*

PUBLICATION RECORD

Submitted

Rull, V. Origin, evolution and decline of European mangroves: the Cenozoic paleobotanical record. *EarthArXiv*, https://eartharxiv.org/repository/view/11757/. Submitted to *Earth-Science Reviews*.

Rull, V., d'Andrea, W., Stein, R., Balascio, N.L., Bradley, R.S., Curtin, L., Petet, D.M., Rapu, R., Seelenfreund, A. Climate change and sociecological shifts on Rapa Nui (Easter Island): Transformation under environmental constraint. Submitted to *AMBIO*.

Rull, V. Author citation metrics in paleontology: the h-index and the c-score. *EarthArXiv*, https://eartharxiv.org/repository/view/10441/. Submitted to *Historical Biology*.

Rull, V. The Anthropocene: epoch, event, historical phase or nothing at all?. *EarthArXiv*, https://eartharxiv.org/repository/view/10764/. Submitted to *Anthropocene Science*.

2026

Rull, V. in press. The role of Quaternary spatiotemporal gradients and disequilibrium dynamics in shaping the present Neotropical biotic patterns. In: Myster, R. (ed.), *Neotropical Ecosystem Change as Temporal and Spatiotemporal Gradients*. Springer Nature, Cham.

Rull, V. 2026. Rethinking glacial retraction and postglacial expansion of the Neotropical palm *Mauritia*. *Journal of Quaternary Science*, doi 10.1002/jqs.70060.

Rull, V., Vicente, A., Bouchal, J.M., Casanovas-Vilar, I. 2026. On the use of extant Middle-East mangroves as modern analogs for Miocene Mediterranean-Paratethyan mangroves. *Palaeobiodiversity and Palaeoenvironments*, doi 10.1007/s12549-025-00693-y.

Rull, V. 2026. Does solo publication still make sense? *EMBO Reports*, 27: 566-569.

Rull, V. 2026. Goodbye H-index, welcome c-score. *Journal of Scolarly Publishing*, 57: 1-11.

Rull, V. 2026. Author position ratio (APR): a simple complementary bibliometric descriptor of authorship patterns. *Journal of Informetrics*, 20: 101776.

Vegas-Vilarrúbia, T., Sacristán-Soriano, O., Borrego, C.M., Corella, J.P., Errea, P., Buchaca, T., **Rull. V.** 2026. Five centuries of lake deoxygenation and microbial shifts revealed by sedimentary DNA. *Anthropocene* 53, 100504.

2025

Rull, V. 2025. Challenges in using modern pollen analogs for Cenozoic paleoecology: examples from the European Neogene. *Lethaia*, 59: 1-9.

Stein, R., Balascio, N.L., Bradley, R.S., Curtin, L., Peteet, D.M., Rapu, R., **Rull, V.**, Seelenfreund, A., D'Andrea, W.J. 2025. Prolonged drought on Rapa Nui during the decline of melalithic monument construction. *Communications Earth & Environment*, 6: 865.

Vegas-Vilarrúbia, T., Blasco, A., Garcés-Pastor, S., Blaauw, M., Calero, M.A., **Rull, V.** 2025. Tracing organic carbon dynamics in a Pyrenean peat bog during the Late-Glacial-Early Holocene transition. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 680: 113330.

Rull, V. 2025. Insights on the indicator capacity of *Artemisia* pollen in pre-Holocene paleoecology. *Palynology*, 49: 2499121.

Rull, V. 2025. Where were the Caribbean mangroves during the Last Glacial Maximum? A preliminary microtopographical appraisal. *Estuarine, Coastal and Shelf Science*, 323: 109404.

Rull, V. 2025. A critical evaluation of fossil pollen records from the mangrove tree *Pelliciera* beyond the Neotropics: biogeographical and evolutionary implications. *Review of Palaeobotany and Palynology*, 335: 105299.

Rull, V. 2025. The Global Humanization Event (GHE). *The Holocene*, 35: 111-112.

2024

Rull, V. 2024. *Origin and Evolution of Caribbean Mangroves. A Time-Continuum Approach*. Springer Nature, Cham.

Rull, V., Vegas-Vilarrúbia, T. 2024. *Vegetation and Landscape Dynamics on the Iberian Pyrenees During the Last 3000 Years. The Montcortès Palynological Record*. Springer Nature, Cham.

Rull, V., Sigró, J., Vegas-Vilarrúbia, T. 2024. *Cannabis* pollen sources and dispersal in the Iberian Pyrenees during the last century: preliminary results and proposals for future studies. *Review of Palaeobotany and Palynology*, 331: 105208.

Rull, V., Blasco, A., Calero, M.A., Vegas-Vilarrúbia, T. 2024. Bassa Nera II. In: Carrión, J.S. (ed.), *Iberian Paleoflora and Paleovegetation. Vol. III: Holocene*. Universidad Politécnica, Cartagena, pp. 83-85.

Montoya, E., **Rull, V.**, Trapote, M.C., Vegas-Vilarrúbia, T. 2024. Montcortès. In: Carrión, J.S. (ed.), *Iberian Paleoflora and Paleovegetation. Vol. III: Holocene*. Universidad Politécnica, Cartagena, pp. 553-556.

Rull, V., Vegas-Vilarrúbia, T., Cañellas-Boltà, N. 2024. Sant Maurici Lake. In: Carrión, J.S. (ed.), *Iberian Paleoflora and Paleovegetation. Vol. III: Holocene*. Universidad Politécnica, Cartagena, pp.731-733.

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Rull, V. 2024. The oldest Holocene Caribbean mangroves and postglacial sea level rise: biogeographical implications. *Quaternary*, 7: 38.

Rull, V. 2024. The Rapa Nui Little Ice Age drought: evidence, potential causes and socioecological impact. *Journal of Biogeography*, 51:1014-1017.

Rull, V., Blasco, A., Sigró, J., Vegas-Vilarrúbia, T. 2024. Last-century forest dynamics in a highland Pyrenean national park and implications for conservation and management. *Plants*, 13: 1144.

Rull, V. 2024. The 'Anthropocene': *alea iacta est*. *EMBO Reports*, 25: 939-943.

Rull, V., Alba, D., Casanovas-Vilar, I. 2024. Middle Miocene vegetation of the Vallès-Penedès Basin (NE Iberian Peninsula), as recorded by fossil pollen analysis: state of the art and future prospects. *Review of Palaeobotany and Palynology*, 321: 105042.

2023

Rull, V. 2023. An updated review of fossil pollen evidence for the study of the origin, evolution and diversification of Caribbean mangroves. *Plants*, 12: 3852.

Rull, V., Blasco, A., Calero, M.A., Blaauw, M., Vegas-Vilarrúbia, T. 2023. A continuous centennial Late Glacial-Early Holocene (15-10 cal kyr BP) palynological record from the Iberian Pyrenees and regional comparisons. *Plants*, 12: 3644.

Rull, V. 2023. Settlement and anthropization of the Azores Islands. *Journal of Biogeography*, 50: 2008-2011.

Rull, V. 2023. Anticipation, discovery and serendipity in Quaternary paleoecology: personal insights from the Iberian Pyrenees. *Quaternary*, 6: 42.

Rull, V., Sigró, J., Vegas-Vilarrúbia, T. 2023. Present climate of Lake Montcortès (central Pyrenees): paleoclimatic relevance and insights on future warming. *Cuadernos de Investigación Geográfica (Geographical Research Letters)*, 49: 23-38.

Rull, V. 2023. Human settlement and landscape anthropization of remore oceanic islands: a comparison between Rapa Nui (Pacific Ocean) and the Azores (Atlantic Ocean). *Plants*, 12: 2089.

Rull, V. & Vegas-Vilarrúbia, T. 2023. A recent *Cannabis* pollen increase on the Iberian Pyrenees. *Science of the Total Environment*, 886: 163947.

Rull, V. 2023. Eocene/Oligocene global disruption and the revolution of Caribbean mangroves. *Perspectives in Plant Ecology, Evolution and Systematics*, 59: 125733.

Rull, V. 2023. Rise and fall of Caribbean mangroves. *Science of the Total Environment*, 885: 163851.

Rull, V., Vegas-Vilarrúbia, T. 2023. Resilience of Pyrenean forests after recurrent historical deforestations. *Forests*, 14: 567.

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Rull, V., Burjachs, F., Carrión, J.S., Ejarque, A., Fernández, S., López-Sáez, J.A., Luelmo-Lautenschlaeger, R., Ochando, J., Pérez-Díaz, S., Revelles, J., Riera, S., Rodríguez, S. 2023. Historical biogeography of *Cannabis* in the Iberian Peninsula: a probabilistic approach based on palynological evidence. *Perspectives in Plant Ecology, Evolution and Systematics*, 58: 125704.

Rull, V. & Vegas-Vilarrúbia, T. 2023. La indústria del cànem al Pirineu. La història que ens expliquen els sediments de l'estany de Montcortès. *Mètode*, 119: 31-36.

2022

Vegas, T., **Rull, V.**, Blasco, A., Calero, M.A., Garcés, S., Cañellas-Boltà, N. 2022. LACEN: lagos centinela de cambio global en los parques nacionales. RED, 10: 25.

Blasco, A., **Rull, V.**, Calero, M.A., Cañellas-Boltà, N., Garcés, S., Vegas-Vilarrúbia, T. 2022. LACEN – llacs sentinella de canvi global en els parcs nacionals: análisis multidisciplinari dels últims 6000 anys. *XII Jornades sobre Recerca al Parc Nacional d'Aigüestortes I Estany de Sant Maurici*, Espot, pp. 47-52.

Calero, M.A., Schulte, L., **Rull, V.**, Vegas-Vilarrúbia, T. 2022. Profunditat de l'Estany de Sant Maurici abans de 1953. *XII Jornades sobre Recerca al Parc Nacional d'Aigüestortes I Estany de Sant Maurici*, Espot, pp. 53-56.

Rull, V. 2022. Paleoecology helps optimize restoration efforts by identifying unrealistic preanthropic targets. *PAGES Magazine*, 30: 18-19.

Montoya, E., **Rull, V.**, Trapote, M.C., Vegas-Vilarrúbia, T. 2022. Montcortès. In: Carrión, J.S. (ed.), *Paleoflora y Paleovegetación Ibérica, Volumen III: Holoceno*. Fundació Séneca, Murcia, pp. 744-751.

Rull, V., Stevenson, C.M. (eds.). 2022. *The Prehistory of Rapa Nui (Easter Island): Towards an Interdisciplinary Integrative Framework*. Springer Nature, Cham.

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Rull, V. 2022. Prehistoric paleoecology of Easter Island. In: Rull, V., Stevenson, C.M. (eds.), *The prehistory of Rapa Nui (Easter Island): Towards an Interdisciplinary Integrative Framework*. Springer Nature, Cham, pp. 275-309.

Rull, V., Stevenson, C.M. 2022. Towards a holistic approach to Easter island prehistory. In: Rull, V., Stevenson, C.M. (eds.), *The prehistory of Rapa Nui (Easter Island): Towards an Interdisciplinary Integrative Framework*. Springer Nature, Cham, pp. 609-626.

Rull, V. 2022. Responses of Caribbean mangroves to Quaternary climatic, eustatic and anthropogenic drivers of ecological change: a review. *Plants*, 11: 3502.

Rull, V., Sacristan-Soriano, O., Sánchez-Melsió, A., Borrego, C.M., Vegas-Vilarrúbia, T. 2022. Bacterial phylogenetic markers in lake sediments provide direct evidence for historical hemp retting. *Quaternary Science Reviews*, 295: 107803.

Rull, V. 2022. Inductive prediction in biology. *EMBO Reports*, 23: e54846.

Rull, V. 2022. The Caribbean mangroves: an Eocene innovation with no Cretaceous precursors. *Earth-Science Reviews*, 231: 104070.

Rull, V., Vegas-Vilarrúbia, T. 2022. Climatic and anthropogenic drivers of forest succession in the Iberian Pyrenees during the last 500 years: a statistical approach. *Forests*, 13: 622.

Rull, V. 2022. Origin, early expansiOn, domestication and anthropogenic diffusion of *Cannabis*, with emphasis on Europe and the Iberian Peninsula. *Perspectives in Plant Ecology, Evolution and Systematics*, 55: 125670.

Rull, V. 2022. On predictions and laws in biological evolution. *EMBO Reports*, 23: e54392.

Vegas-Vilarrúbia, T., Corella, J.P., Sigró, J., **Rull, V.**, Dorado-Liñán, I., Valero-Garcés, B.L., Gutiérrez-Merino, E. 2022. Regional precipitation trends since 1500 CE reconstructed from calcite sublayers of a varved Mediterranean lake record (central Pyrenees). *Science of the Total Environment*, 826: 153773.

Rull, V. 2022. Biodiversity crisis or mass extinction? *EMBO Reports*, 23: e54193.

2021

Rull, V., Vegas-Vilarrúbia, T. 2021. Conifer forest dynamics in the Iberian Pyrenees during the Middle Ages. *Forests*, 12: 1685.

Rull, V., Vegas-Vilarrúbia, T., Corella, J.P., Trapote, M.C., Montoya, E., Valero-Garcés, B. 2021. A unique Pyrenean varved record provides a detailed reconstruction of Mediterranean vegetation and land-use dynamics over the last three millennia. *Quaternary Science Reviews*, 268: 107128.

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Rull, V., Vegas-Vilarrúbia, T., Corella, J.P., Valero-Garcés, B. 2021. Bronze Age to Medieval vegetation dynamics and landscape anthropization in the southern-central Pyrenees. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 571: 110392.

Rull, V., Vegas-Vilarrúbia, T. 2021. A spatiotemporal gradient in the anthropization of Pyrenean landscapes. Preliminary report. *Quaternary Science Reviews*, 258: 106909.

Rull, V. 2021. Contributions of paleoecology to Easter Island's prehistory: a thorough review. *Quaternary Science Reviews*, 252: 106751.

Rull, V. 2021. Pristinity, degradation and replacement: the three dimensions of human impact on island vegetation. *Progress in Physical Geography*, 45; 407-426.

2020

Rull, V. 2020. *Paleoecological Research on Easter Island. Insights on Settlement, Climate Change, Deforestation and Cultural Shifts.* Elsevier, Amsterdam.

Rull, V. 2020. *Quaternary Ecology, Evolution and Biogeography*. Academic Press, London.

Vegas-Vilarrúbia, T., **Rull, V.**, Trapote, M.C., Cao, M., Rosell-Melé, T., Buchaca, T., Gomà, J., López, P., Sigró, J., Safont, E., Cañellas, N., Garcés-Pastor, S., Giralt, S., Corella, P., Zanón, N. 2020. Modern analog approach applied to high-resolution varved sediments – a synthesis for Lake Montcortès (Central Pyrenees). *Quaternary*, 3: 1.

Cao, M., Rivas-Ruiz., Trapote, M.C., Vegas-Vilarrúbia, T., **Rull, V.**, Rosell-Melé, A. 2020. Seasonal effects of water temperature and dissolved oxygen on isoGDGT proxy (TEX86) in a Mediterranean oligotrophic lake. *Chemical Geology*, 551: 119759.

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Rull, V. 2020. The deforestation of Easter Island. *Biological Reviews*, 95: 124-141.

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Rull, V., Vegas-Vilarrúbia, T. 2020. The Pantepui "lost world": towards a biogeographical, ecological and evolutionary synthesis of a pristine Neotropical sky-island archipelago. In: Rull, V., Carnaval, A. (eds.), *Neotropical Diversification: Patterns and Processes.* Springer, Berlin, pp. 369-413.

2019

Rull, V., Vegas-Vilarrúbia, T., Huber, O., Señaris, C. (eds.). 2019. *Biodiversity of Pantepui, the Pristine 'Lost World' of the Neotropical Guiana Highlands*. Academic Press, London.

Rull, V., Vegas-Vilarrúbia, T., Huber, O., Señaris, C. Introduction. In: Rull, V., Vegas-Vilarrúbia, T., Huber, O., Señaris, C. (eds.), *Biodiversity of Pantepui: the pristine 'Lost World' of the Neotropical Guiana Highlands*. Academic Press, London, pp. xv-xviii.

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MAIN CONTRIBUTIONS

GENERAL AND CONCEPTUAL ISSUES

Time continuum, ecology and paleoecology

There is one single biosphere that has persisted since the origin of life and has operated under the same ecological, evolutionary and biogeographical principles. Therefore, any biotic pattern at any particular time slice, including our own current world, may be explained using a single time-continuum framework. Within a time-continuum approach, past present and future are human constructions, and the distinction between ecology and paleoecology is artificial. The term "ecology" should be used in a general sense, not limited to the modern world but including all biotic and abiotic interactions since the origin of life. Life cannot exist without ecological relationships.

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Latitudinal diversity gradients

Neotropical biodiversity originated in a continuous fashion from the Oligo-Miocene to the Pleistocene, with no significant bursts at any particular time interval. Tectonics (orogeny), continental drift, and climate changes, as well as their feedbacks and synergies, have contributed to Neotropical diversification continuously through time. The old debate over a Neogene versus Pleistocene origin of Neotropical biodiversity is no longer relevant.

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Microrefugia

The occurrence of small localized areas with favorable microenvironments within regionally unfavorable conditions (microrefugia), situated beyond the main distribution area (macrorefugia) of species and their communities, contributed to their survival during Pleistocene glacial/interglacial cycles. These microrefugia are classified as peripheral, diffuse or remote, in relation to the macrorefugia. Microrefugia, whether natural or anthropogenic, could be useful for conservation purposes in a warming world.

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Disequilibrium dynamics in ecology

The combination of thermodynamic and biotic disequilibrium dynamics clarifies the role of Pleistocene glacial/interglacial cycles in shaping current biota and ecosystems. The "normal" or maximum-entropy stable state is a glaciation, whereas interglacials are punctuated inputs of external energy leading to anomalous short-lived warmings that organisms have to endure to persist. Many organisms, especially those with longer generation spans, are unable to follow these continuous environmental shifts and are in permanent disequilibrium with the enviroment.

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Evolutionary laws and physical reductionism

The evolutionary time arrow runs against the thermodynamic time arrow, as it tends to minimize entropy by increasing biological complexity. Unlike physics, biological knowledge does not advance by testing predictions (top-down) but by finding regularities in empirical observations (bottom-up). Attempting to find general biological laws similar to those of physics is futile. Life cannot be reduced to physical laws due to the existence of emergent properties, unpredictable evolutionary trends and contingency. Life could be viewed as an anomaly between the laws of particle physics and those of the universe as a whole (e.g., gravitational laws).

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Complex natural-anthropogenic ecosystems

Complex scenarios characterized by continuous and fast-evolving interactions between natural and human-induced factors in highly dynamic environments are reliably addressed using a conceptual model called EHLFS (Environment/Humans/Landscape Feedbacks and Synergies). This framework is sufficiently broad to encompass conditions ranging from environmental to anthropogenic determinism, along with any intermediate state involving different degrees of human adaptation, resilience and niche construction, as integrated in the so-called human ecodynamics approach. The model was initially designed for Easter Island (see below), but it is adaptable to a variety of system dynamics involving biophysical and social interactions.

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Niche conservatism and Cenozoic modern analogs

Many paleoclimatic and paleoecological inferences are based on the undemonstrated assumption of niche conservatism (NC) over time. These inferences use the current climatic and ecological requirements of extant taxa—referred to as Nearest Living Relatives (NLRs)—to perform qualitative and quantitative paleoenvironmental reconstructions throughout the Cenozoic. The reliability of NC assumptions is high for the Quaternary but decreases with time, and establishing a limit beyond which modern pollen analogies remain valid remains problematic. A review of selected reconstructions based on NC premises and the use of NLR techniques concludes that these assumptions are unwarranted, even for the Neogene. Therefore, empirical testing of NC for the taxa

used and the time interval considered is fundamental, yet it is rarely performed. The use of pollen-indepedent paleoclimatic proxies and staistitcal paleocommunity approaches is recommended.

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Stability and potential natural vegetation

When vegetation trends are analyzed from a long-term perspective using palaeoecological records, the concept of potential natural vegetation (PNV) is unsupported. Although some records show millennial-scale stability in the absence of natural or anthropogenic disturbance, these cases are the exception rather than the rule and undergo significant shifts when disturbances occur. Therefore, long records of stability do not constitute valid evidence for PNV.

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REGIONAL STUDIES

Origin and evolution of mangroves

Caribbean region

The Caribbean mangroves originated in the Early-Middle Eocene, underwent a fundamental community turnover at the Eocene/Oligocene transition (EOT), and diversified in the Neogene to attain their present geographical and diversity patterns. Anthropization began in the Middle Holocene, approximately 6000 years ago. The founding mangrove-forming tree was *Pelliciera*, which is restricted to the Atlantic-East Pacific (AEP) biogeographical region, and was replaced by *Rhizophora*, which is thought to have arrived from the Indo-West Pacific (IWP) region during the Late Eocene. This contrasts with the traditional view that earlier mangroves were widespread across the pantropical Tethys Sea during the Late Cretaceous.

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Europe

Currently, Europe is devoid of mangroves due to its high latitude and the corresponding environmental conditions, but these communities were present from the Paleocene/Eocene boundary until the Pliocene. These mangroves flourished during the Early-Middle Eocene, coinciding with a hothouse Earth state and sea levels higher than at present. After a significant reduction to southern localities during the Eocene/Oligocene cooling and sea-level drop, European mangroves underwent a slight expansion during the Middle Miocene Climatic Optimum (MMCO). This was followed by a second bottleneck during the Messinian salinity crisis, leading to their disappearance during the Pliocene.

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Paleoecology of remote and pristine Neotropical areas

Pantepui

Pantepui is a biogeographical province of the Neotropical region formed by the assemblage of table-mountain (tepui) summits of the Guiana Highlands – the famous "Lost World" of Arthur Conan Doyle, situated between the Amazon and Orinoco basins – above 1500 m elevation. The unique Pantepui biota is highly diverse and endemic, and its origin remains debated. Paleoecological evidence supports a mixed origin, as a combination of long-standing summit species, which evolved by vicariance, with others that migrated up and down during the Pleistocene glacial-interglacial cycles, thus promoting gene flow among tepuis. Contrary to traditional assumptions, Pantepui underwent significant climatic shifts during the Quaternary but was not arid and devoid of vegetation during the Last Glacial Maximum (LGM).

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Gran Sabana

The Gran Sabana (GS) is part of the Roraima savannas, a huge savanna patch (~70,000 km²) within the Amazon/Orinoco rainforests. The origin of these savannas is debated and is attributed to either natural drivers —as a remnant of the assumedly arid Neotropical lowlands during the Last Glacial Maximum (LGM)— or anthropogenic ones, such as deforestation by fire. Paleoecological studies have shown that the GS, now covered by extensive savannas and forest-savanna mosaics, supported a more closed vegetation during the Lateglacial, which was progressively opened, coinciding with significant fire events. The last of these events occurred approximately 2000 years ago, when forest clearing accelerated and became more frequent, thus inhibiting forest regeneration. The same practices continue at present, leading to net savanna expansion to the detriment of forests. With the available evidence, the most likely explanation is that the GS landscape has largely been shaped by human activities, notably deforestation by fire.

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Orinoco delta

Palaeoecological records from the Orinoco delta and its surroundings have allowed for the reconstruction of Holocene sea-level rise along the southern Caribbean coasts. These records reveal the impact of sea-level changes on coastal and inland ecosystems, particularly mangroves and *Mauritia* palm communities (see "historical biogeography of iconic taxa"), both of which were affected by marine and brackish water flooding. The steady increase in sea levels was not compensated by delta accretion in the Early Holocene, when the rate of sea-level rise was at its maximum. This eustatic trend stabilized in the Middle Holocene, and delta accretion resulted in the net advancement of the coastal front toward the sea. This progradation would have favored the establishment of human populations.

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Human settlement of remote oceanic islands and ecological consequences

Rapa Nui/Easter Island

The first complete and continuous (gap-free) paleoecological records of the interval between the Polynesian colonization of Easter Island/Rapa Nui (800–1200 CE) and the arrival of Europeans (1722 CE) demonstrate that deforestation was not abrupt and synchronous, as usually assumed, but spatiotemporally heterogeneous. The main driver of cultural reorganization in ancient Rapanui society was the general unavailability of freshwater caused by a century-scale, pronounced drought that occurred between 1570 CE and 1700 CE. These results do not support the traditional "ecocidal" view of a self-induced demise of the Rapanui society due to the overexploitation of natural resources. Rather, the ancient Rapanui proved resilient to environmental and ecological shifts, with the actual collapse being triggered by the introduction of epidemic diseases and slave trading following European contact.

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Azores Islands

Human occupation of the Azores Islands predated the official Portuguese colonization (1449 CE) by at least a century and a half. This was based on the finding of pollen from cultivated cereals (rye), spores of coprophilous fungi as proxies for animal husbandry, and charcoal as an indicator of fire in the sediments of Lake Azul (São Miguel Island). These findings were attributed to the existence of small, possibly itinerant populations on the island. The removal of the original laurisilvas, followed by a succession of massive introductions of exotic cultivated and forest species after Portuguese settlement, was documented by pollen analysis, in close agreement with the detailed historical reports available. This represents a large-scale experiment on community assembly by combining plants of diverse origins, such as the Mediterranean, South Africa, and Eastern Asia.

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Elevational anthropization patterns

Using the Iberian Pyrenees as a pilot study area, it has been suggested that, in mountain ranges, anthropization—defined as the deep landscape transformation by humans, usually through deforestation and the establishment of crops, pastures, and urbanization—has progressed upward during the Holocene. In the Pyrenean range, this process started in the lowlands during the Bronze Age and reached alpine areas by the Middle Ages. The significant average rate of anthropization was 40 m in elevation per century, with accelerations during warmer phases, especially the Medieval Warm Period (MWP).

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KEYSTONE PALEORECORDS

Northern Andes

High-elevation lake and peat bog coring enabled the documentation of the first unequivocal records of keystone paleoclimatic events, such as the Last Glacial Maximum (LGM), the Younger Dryas (YD) climatic reversal and the Little Ice Age (LIA), in the Neotropics (northern Andes), as well as their consequences for vegetation dynamics. In the case of LIA cooling, solar activity cycles were identified as the main paleoclimatic drivers.

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Lake Montcortès

The Lake Montcortès record (Iberian Pyrenees) is the first paleoecological record of a complete, continuous (gap-free), and absolutely dated varved sedimentary sequence covering the last 3000 years in the western Mediterranean. This sequence is the longest and highest-resolution record available and is considered a standard reference section for the Mediterranean region. It has allowed for the recording of three major regional deforestation-recovery events (Roman, Medieval and Modern) and their main anthropogenic drivers. Forest recovery has been almost complete, showing high resilience. The sequence provides a high-resolution reconstruction of the use of Lake Montcortès as a regional hemp-retting site from the 16th to the 19th centuries, supplying fiber for the Spanish army (ropes, sails) during the period of imperial expansion. It has also allowed for the detection and location of illegal *Cannabis* cultivation in the surrounding area over the past few years.

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Pyrenean Lateglacial

The first complete, continuous (gap-free), high-resolution Lateglacial record from the Iberian Pyrenees was retrieved from the Bassa Nera site. This site was glaciated during the Last Glacial Maximum, and the sequence contained the classical stadial-interstadial succession characteristic of the deglacial trend between 15 and 10 ka BP. The responses of vegetation to these paleoclimatic events and the process of peat accumulation were assessed and compared with regional patterns. Contrary to widely accepted but unproven views, the Younger Dryas (YD) was found to be a relatively wet event.

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Chrysophyte stomatocysts

The pioneering record of Chrysophyte stomatocysts in lake sediments across the Iberian Peninsula was obtained at the Pla de la Llagona site in the Pyrenees. This allowed the first cyst assemblage to be carefully described and identified, and its utility in paleoecological reconstruction to be assessed. Similarly, a unique and unexpected modern assemblage of Chrysophyte stomatocysts, characteristic of cold temperate areas, was obtained in a tropical environment at the Caribbean Playa Medina site.

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Multiproxy studies

The use of physico-chemical and biological proxies other than pollen and spores has enabled the reconstruction of paleoclimatic trends across various regions. For instance, the Montcortès record provided a high-resolution (annual) reconstruction of precipitation trends and lake oxygenation shifts over the last five centuries based on varve thickness. In the Azores Islands, a multiproxy framework was used to study the influence of the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO) on hydroclimatic trends during a similar interval. In Easter Island, geochemical proxies were used to infer the influence of the South Pacific Convergence Zone (SPCZ) and the Southern Westerlies (SW) on hydroclimatic shifts over the last 70,000 years.

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HISTORICAL BIOGEOGRAPHY OF ICONIC TAXA

Mauritia

Mauritia, one of the most common and widespread palms in the Amazon and Orinoco basins, survived the Last Glacial Maximum (LGM) in scattered lowland microrefugia and expanded across the whole tropical South America, up to ~1000 m elevation, during the Lateglacial-Holocene. Cooling, rather tha aridity, was the primary driver of LGM retraction. During the last 2000 years, the main dispersal agents are thought to have been indigenous populations, as the palm is widely used for multiple purposes and its colonization of fire-cleared is favored.

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Cannabis

The first records of *Cannabis*, likely in its wild form, in the Iberian Peninsula (IP) date from the Paleoelithic (150-12 ka BP). The first records of introduction, probably in cultivated form, are from the Neolithic (7-5 ka BP). A significant expansion occurred in the Middle Ages (1.5 ka BP), after a phase of stability and internal expansion during the Late Bronze and the Roman Epoch. Maximum

cultivation and hemp retting occurred between 16th and 19th centuries. *Cannabis* pollen deposited in lake sediments serves as a proxy to detect illegal cultivation.

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Pelliciera

Pelliciera is a mangrove tree that is currently restricted to a small patch around the Panama Isthmus; however, in the Oligo-Miocene, its range extended across most of the Neotropics. There are numerous records also from North America, Europe and west Africa that question its Neotropical exclusivity. A comprehensive critical review of these extra-Neotropical records based on pollen images and descriptions concluded that only a few African records are compatible with *Pelliciera* occurrence, ranging from the Eocene to the Plio-Pleistocene. This confirms the Atlantic East-Pacific (AEP) nature of this taxon and questions biogeographical and evolutionary insights based on its potential occurrence in North America and Europe.

References:
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FUTURE EARTH

Paleoecology and conservation

Palaeoecological records from pre-anthropogenic periods provide past analogues for the response of extant species and ecosystems to ongoing global change, primarily warming and sea-level rise. These studies help disentangle natural and anthropogenic drivers of ecological change and identify baselines for conservation and restoration practices. However, they also contribute to identifying unrealistic and unfeasible restoration targets resulting from climatic, cultural and economic constraints.

References:
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- Rull V et al (2016) *Holocene* 26, 1162-1167
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- Rull V (2022) *PAGES Magazine* 30, 18-19
- Rull V (2023) *Science of the Total Environment* 885, 163851
- Rull V, Vegas-Vilarrúbia T (2023) *Forests* 14, 567
- Rull V et al (2024) *Plants* 13, 1144

Past analogs for current global warming and sea-level rise

Younger Dryas

The passage from the Lateglacial to the Holocene, represented by the Younger Dryas/Early Holocene transition (YD/EH), constituted a global warming that is comparable in extent, magnitude and rates to the ongoing global warming. Therefore, the YD/EH climatic shift and the corresponding biotic

responses may be used as modern analogs for the current warming, with applications for biodiversity and ecosystem conservation.

References:

- Vegas-Vilarrúbia T et al (2011) *Quaternary Science Reviews* 30, 2361-2388
- Rull V et al (2015) *Quaternary Science Reviews* 115, 28-38

Upward migration and habitat loss

Paleoecological investigations revealing the occurrence of up and down species' migration following climatic shifts in the pristine summits of the Neotropical Guiana Highlands, also known as Pantepui (see "Paleoecology of remote and pristine Neotropical areas"), have been used to simulate how ongoing global warming could affect this biota in the near future. It has been estimated that 75–80% of vascular plant species could become extinct due to habitat loss by the end of this century, of which 30–50% are endemics. Given the uniqueness of the Pantepui flora, these extinctions would be of a global nature. Potential conservation actions include the creation of protected areas, germplasm banks and managed relocation.

References:

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- Nogué S et al (2009) *Climatic Change* 94, 77-85
- Rull V et al (2009) *Conservation Biology* 23, 1323-1327
- Safont E et al (2012) *Biological Conservation* 149, 113-121
- Safont E et al (2014) *Systematics and Biodiversity* 12, 292-314
- Rull V et al (2016) *Diversity and Distributions* 22, 995-999
- Safont E et al (2016) *Systematics and Biodiversity* 14, 327-344
- Rull V, Vegas-Vilarrúbia T (2017) *Frontiers in Plant Science* 8, 81
- Rull V et al (2019) *Biodiversity of Pantepui, the Pristine "Lost World" of the Neotropical Guiana Highlands*. Academic Press, London (Chapter 17).

Megadelta flooding

Previous palaeoecological studies in the Orinoco Delta have emphasized the reliance of its ecosystems and human populations on the balance between sea-level rise and delta accretion rates (see "Palaeoecology of remote and pristine Neotropical areas"). The predicted sea-level rise for this century could be rapid enough to lead to the general inundation of the delta, which ecosystems and indigenous populations could be unable to cope with. This would become an additional factor favoring species' extinction through habitat loss and deep cultural transformations. This could also be the fate for many other megadeltas globally, especially in tropical regions. The threat is particularly critical in overpopulated deltas, which account for approximately 40% of the total.

References:

- Vegas-Vilarrúbia T et al (2015) *Science of the Total Environment* 515-516, 129-142
- Vegas-Vilarrúbia T, Rull V (2016) *Frontiers in Ecology and Evolution* 4, 77

The Anthropocene debate

After the rejection of the Anthropocene as a new epoch following the Holocene by the International Commission on Stratigraphy (ICS), global Earth's anthropization is better described as a geological event, called the Global Humanization Event (GHE), starting with the Late Pleistocene megafaunal extinctions and culminating after the Great Acceleration. It would also be possible to revive Stoppani's concept of the Anthropozoic Era by placing its beginning at the Plio/Pleistocene boundary.

References:

- Rull V (2013) *Holocene* 23, 1198-1201
- Rull V (2016) *Holocene* 26, 1513-1515
- Rull V (2016) *Quaternary Geochronology* 36, 76-77

- Rull V (2017) *Collectanea Botanica* 36, e008
- Rull V (2018) *EMBO Reports* 18, 1056-1060
- Rull V (2018) *Quaternary* 1, 24
- Rull V (2021) *Lethaia* 54, 289-299
- Rull V (2024) *EMBO Reports* 25, 939-943
- Rull V (2025) *Holocene* 35, 111-112

The sixth exctinction

While the current anthropogenic biodiversity crisis, initiated around 1500 CE, has not yet reached the magnitude of a mass extinction as defined paleontologically (75% of species lost), the rate of species loss greatly exceeds natural background extinction rates (NBER) and is already comparable to such events. Conservation actions are urgently needed but they should consider these NBER, as stopping all extinction is nonsensical in evolutionary terms and is as unnatural as accelerating it.

References:
- Rull V (2022) *EMBO Reports* 23, e54193

APPLIED STUDIES

Forest managment in protected sites

Palaeoecological investigations have shown that mid-elevation Pyrenean forests within a Natura 2000 region are resilient to historical deforestation and recovered even after a 60% removal during the Middle Ages. Conservation actions should include effective fire prevention rules and focus on the maintenance of spatial patterns (mosaics) and the associated metapopulation and metacommunity ecological dynamics. In the highlands, high-resolution palaeoecological studies within a national park covering the last century have allowed for the reconstruction of conifer forest dynamics before and after its creation. The main threats are warming, drying, fire and mass tourism; therefore, conservation measures should prioritize these aspects and a strict policy of forest exploitation.

References:
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Oil/gas exploration and production

High-impact palynology (HIP) is an approach that uses multivariate ecostratigraphic tools for high-resolution dating and correlation. It is especially useful for defining the sequence stratigraphic framework in a given basin or field, which contributes to optimizing exploration and production planning, thus reducing investment risk and maximizing resource allocation efficiency. HIP has applications in petroleum-system modeling, drilling optimization, new discoveries and secondary recovery, among others.

References:
- Hambalek N et al (1993) *Boletín de la Sociedad Venezolana de Geólogos* 19, 7-19
- Rull V (1997) *Boletín de la Sociedad Venezolana de Geólogos* 22, 34-36
- Lorente MA et al (1997) *Boletín de Geología* 18, 33-50
- Rull V (2000) *Palaios* 15, 14-24
- Rull V (2002) *American Association of Petroleum Geologists Bulletin* 86, 279-300

Aerobiology and allergology

The first yearly pollen calendar of the Caracas metropolitan area (Venezuela) showed a clear correspondence between airborne pollen, meteorological parameters and seasonal trends in the

immunoglobulin E (IgE) response in a control patient population. Atmospheric pollen concentration peaked in March-April, with *Cecropia*, *Celtis* and Poaceae as the main components (~60% of the total), coinciding with the onset of the rainy season. Fungi spores showed less seasonal behavior and were more closely linked to specific daily precipitation events.

References:

- Perdomo de Ponce D et al (1989) *Investigación Clínica* 30, 13-20
- Perdomo-Ponce D et al (1991) *Investigación Clínica* 32, 157-186

METHODOLOGY

Palynological and paleoecological methods

Improvements in laboratory sample processing, pollen identification and counting, as well as proxy calibration for paleoclimatic estimation. New methods for the introduction of exotic pollen to estimate pollen concentration and influx. Development of pollen atlases for previously unknown regions, especially in the Guiana Highlands (see below). Optimization of statistically reliable pollen counting methods in paleoecology. Development of training sets and transfer functions for previously unstudied areas, such as the northern Andes and the Pyrenees.

References:

- Salgado-Labouriau ML, Rull V (1986) *Review of Palaeobotany and Palynology* 55, 5-17
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- Rull V (1998) *Boletín de la Sociedad Venezolana de Geólogos* 23, 5-24
- Rull V (1988) *Acta Botanica Venezuelica* 21, 43-73
- Rull V, Vegas-Vilarrúbia T (1999) *Micropaleontology* 45, 365-393
- Rull V (2006) *Holocene* 16, 105-117
- Cañellas-Boltà N et al (2009) *Holocene* 19, 1185-1200
- López-Martínez C (2010) *Collectanea Botanica* 29, 31-49
- Montoya E et al (2010) *Palaeogeography, Palaeoclimatology, Palaeoecology* 297, 169-183
- Mercadé A et al (2013) *Collectanea Botanica* 32, 87-101
- López-Vila J et al (2014) *Holocene* 24, 327-345
- Rull V et al (2017) *Journal of Paleolimnology* 57, 95-108
- Trapote M et al (2018) *Palaeogeography, Palaeoclimatology, Palaeoecology* 496, 292-304
- Cao M et al (2020) *Chemical Geology* 551, 119759
- Rull V et al (2023) *Geographical Research Letters* 49, 23-38

Databases

NEODIV. Phylogeographic database of Neotropical species' diversification timing (Eocene to Pleistocene).
CARMA. Palynological database for the study of Caribbean mangroves (Late Cretaceous to Pleistocene).
EIRA. Database of radiocarbon dates from Easter Island's lake/peat sediments (Pleistocene-Holocene).
CHIP. Palynological database for the study of *Cannabis* in the Iberian Peninsula (Pleistocene-Holocene).
PELPOL. Palyonological database for the study of *Pelliciera* evolution (Paleocene to present).
EUMAN. Paleobotanical database for the study of European mangroves (Late Cretaceous to Pliocene).
SRPAL. Citation parameters for paleontologists included in the ranking of world's top 2% scientists (2025).
LAPD. Lantin American Pollen Database (collaboration by providing raw data records from Venezuela).

References:

- Rull V (2008) *Molecular Ecology* 17, 2722-2729

- Rull V (2016) *Frontiers in Ecology and Evolution* 4, 44
- Flantua S et al (2015) *Review of Palaeobotany and Palynology* 223, 104-115
- Flantua S et al (2016) *Climate of the Past* 12, 483-523
- Rull V (2023) *Plants* 12, 3852
- Rull V et al (2023) *Perspectives in Plant Ecology, Evolution and Systematics* 59, 125733
- Rull V (2024) *Origin and Evolution of Caribbean Mangroves.* Springer Nature (Chapter 2)
- Rull V (2025) *Review of Palaeobotany and Palynology*, 335: 105299

SCIENTIFIC EVALUATION

Scientometrics

In citation-based scientific evaluation, the h-index is flawed and should be replaced by better indices, such as the c-score, which addresses the h-index's drawbacks. In addition, these single-number indices should be complemented with semi-quantitative descriptors that account for authorship patterns—specifically first, intermediate and last authors as proxies for true-author, collaborator and manager roles. The APR (Author Position Ratio) is a descriptor of this type that measures the actual contribution of a given author to his or her publication record. Solo authorship should be protected from extinction given the current trend toward the total dominance of multiauthored papers.

References:
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SCIENCE AND SOCIETY

The utility of science

Currently, scientific research is experiencing a clear shift toward immediate applicability, according to societal and industrial needs. This is due to the explicit rules dictated by policymakers, especially in Europe. As a result, the freedom of scientists to choose their research topics and priorities has suffered a heavy blow. Free science has been the engine of knowledge generation and accumulation for centuries, but this era seems to have entered a new "dark age." Knowledge becomes applicable sooner or later, and abolishing free science by decree may stifle the advancement of knowledge, which is the most precious heritage for future generations.

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- Rull V (2014) *EMBO Reports* 15, 919-922
- Rull V (2014) *Collectanea Botanica* 33, 85-90
- Rull V (2016) *EMBO Reports* 17, 131-135

The fallacy of sustainability

Global economic growth based on current rates of exploitation, pollution and waste accumulation on a planet of finite resources is no longer sustainable. This word is often misused in conservation science, but it makes sense when applied to the continuity of the current supercapitalist regime. However, such a system is also unsustainable in the long term due to the physical limits of our planet, also referred to as natural capital. These observations seem trivial, but they are bypassed by political and economic actors.

References:
- Rull V (2010) *EMBO Reports* 11, 659-663
- Rull V (2011) *EMBO Reports* 12, 103-106
- Rull V (2010) *Collectanea Botanica* 29, 103-109
- Rull V (2014) *EMBO Reports* 15, 17-20

OUTREACH

Books and papers on a number of subjects outlined above, such as the Anthropocene, *Cannabis* in the Iberian Peninsula, the prehistory of Easter Island, the utility of science, extinction by habitat loss and the origin of the Gran Sabana.

References:

- Rull V (2003) *Historia Natural* 3, 24-33
- Safont E et al (2010) *L'Atzavara* 20, 29-42
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- Rull V (2022) *Historia National Geographic* 183, 94-111
- Rull V, Vegas-Vilarrúbia (2023) *Mètode* 119, 31-36
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